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GB 1229876 A

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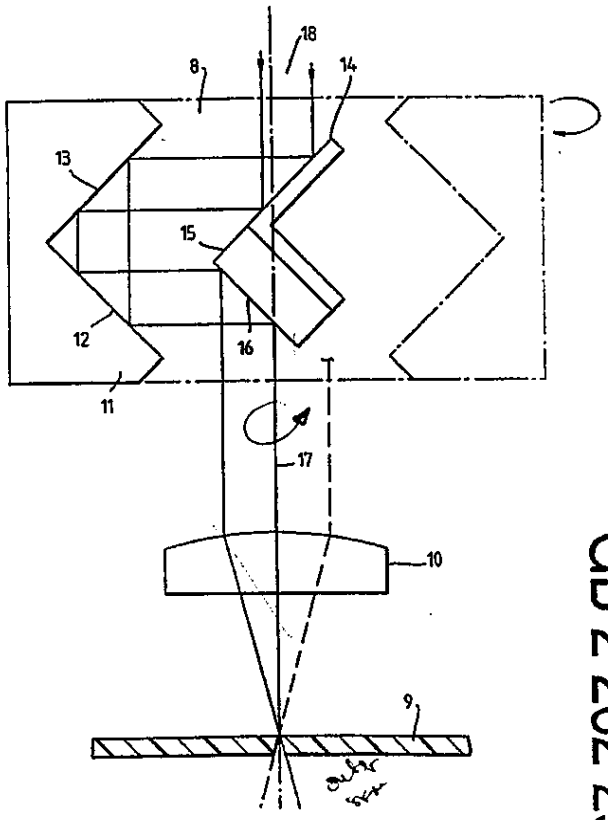
(54) Laser drilling of reverse tapered holes

(57) A method for drilling a series of reverse tapered holes through a surface by means of a laser beam involves projecting the laser beam (18) through a fixed spherical lens (10) located above the surface (9) focusing the laser beam onto the surface such that the taper angle of the beam will substantially conform to the required taper of the hole. The focused beam is rotated about the polar axis of the fixed spherical lens (10) whereby a continuous directional change of laser beam energy is effected through the material (9) after passing through the focal point at the outer surface to give a resultant divergent hole extending therethrough. The apparatus includes a high speed rotating optical assembly (8) positioned above the structural skin (9) with the fixed spherical lens (10) positioned therebetween.

Fig.4.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1.

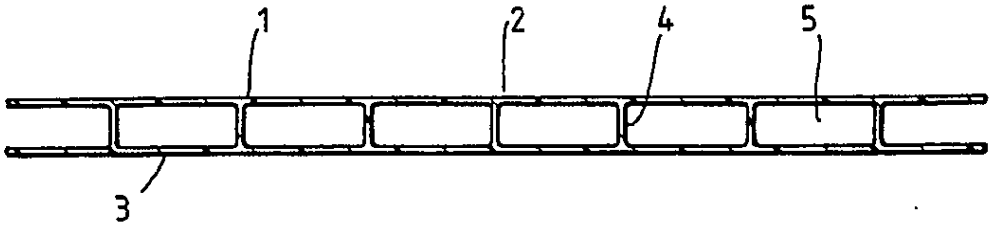


Fig.2.

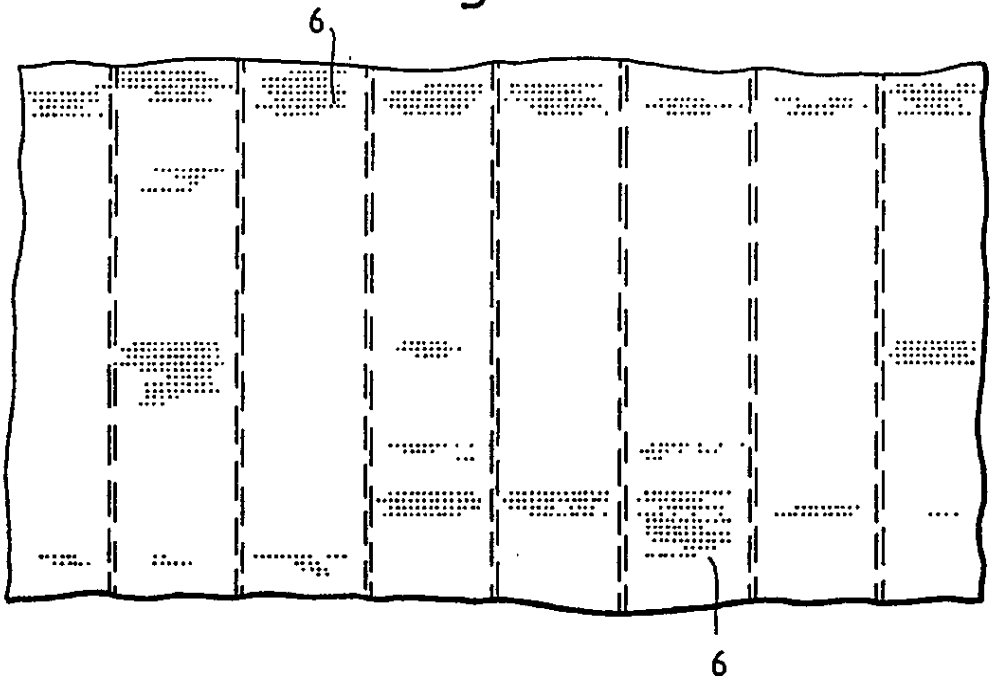


Fig.3.

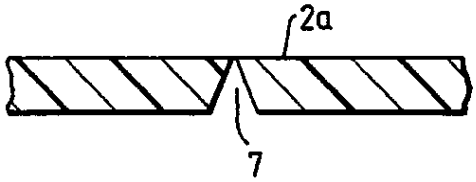


Fig.4.

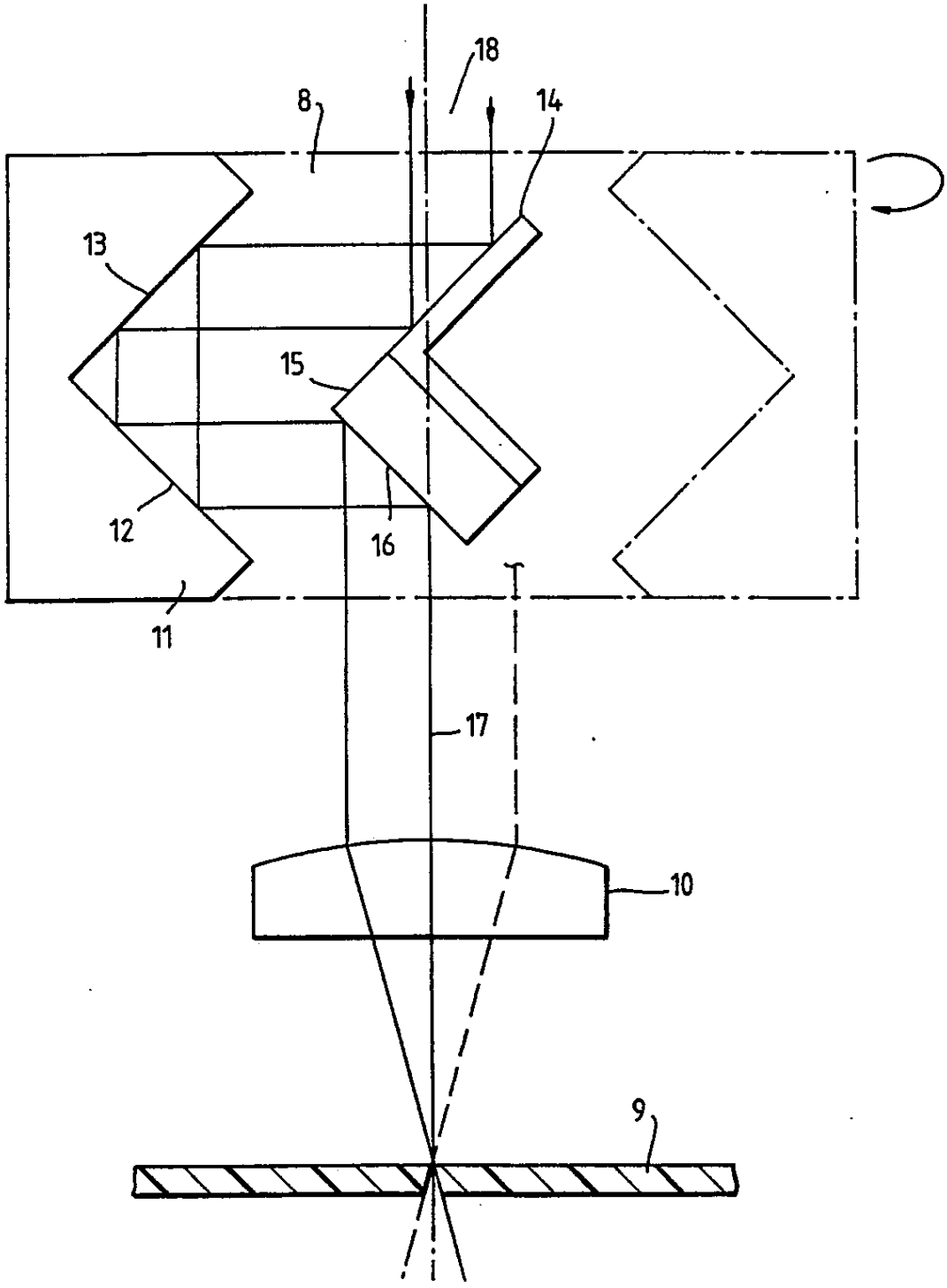
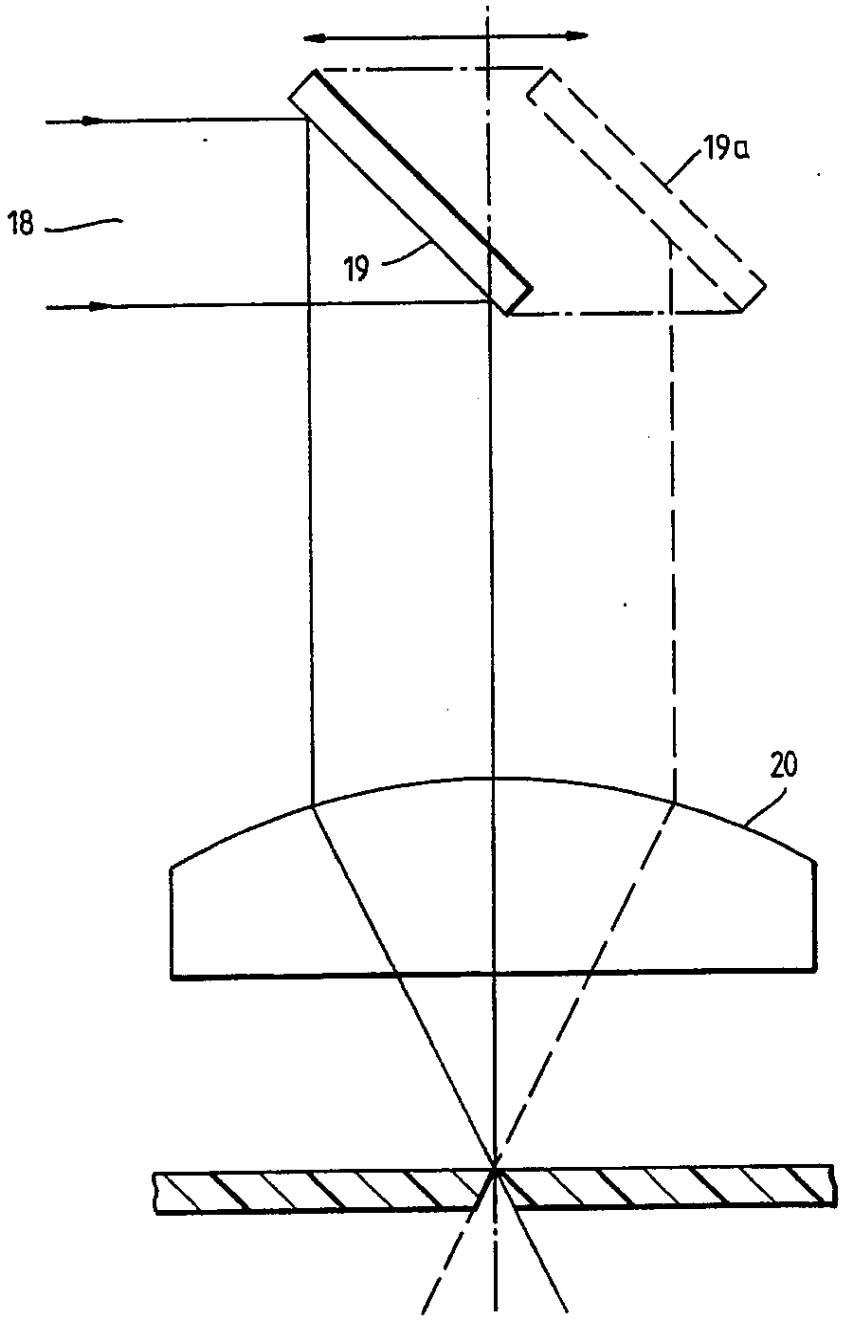


Fig. 5.



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LASER DRILLING OF REVERSE TAPERED HOLES

This invention relates to the drilling of reverse tapered holes by means of a laser beam. More particularly though not exclusively, it relates to a method and apparatus for laser drilling a multiplicity of reverse tapered holes in at least one surface of a pre-formed structural closure and to a structure incorporating a multiplicity of reverse tapered holes manufactured by the said apparatus.

It is known, as exemplified by US Patent 4.857,698 to produce a large number of small holes in a metal sheet, such a sheet being particularly applicable for laminar flow control when employed as a porous wing skin material on aircraft. Suction applied to the inner surface of a wing skin provides a means of removing boundary layer.

It is considered desirable that the holes in the skin should be of reverse taper, that is they diverge inwardly from the skin outer surface, by which means in-flight clogging of the holes is minimised. In a conventionally fabricated structure it is possible to produce holes of tapered form using a single laser pulse per hole, the taper converging from the laser input direction. On assembly the perforated sheet is

then merely reversed and secured to its supporting structure.

In certain instances the structural assembly may be manufactured in advance of the laser drilling such that the undersurface is inaccessible. A one shot laser pulse can therefore not be employed to produce the desired in-situ taper. A structure in which such a problem exists is that produced by a superplastic forming and diffusion bonding process in which a number of sheets, edge welded to define inflatable envelopes and spot-welded along lines defining a desired internal structure, are heated to a desired superplastic forming temperature and then inflated by an injection of low pressure inert gas to the required configuration. Such a structure may include, in its final form, fluid flow passageways the outer surface of which must be perforated to allow the required suction to be applied. The superplastic form inflation process, however clearly will not allow laser drilling in advance of the forming process and, when formed, access from the underside of the outer skin is not possible.

It is accordingly one object of the present invention to provide a method and apparatus for laser drilling a multiplicity of reverse tapered holes in a preformed structural assembly.

It is a further object of the present invention to provide a preformed structural assembly having a multiplicity of reverse tapered holes formed in at least one outer surface by means of a laser beam.

According to one aspect of the present invention there is provided a method of drilling a multiplicity of reverse tapered holes, by means of a laser beam, across at least one surface element of a pre-formed or pre-assembled structure in which each of said holes is formed by projecting said laser beam through a fixed spherical lens located above the outer surface, of said surface element, focusing said laser beam on to the said outer surface such that the taper angle of said beam will substantially conform to the required taper of the hole and rotating said focused beam about the polar axis of said fixed spherical lens whereby a continuous directional change of laser beam energy is effected through the material after passing through the focus point at the outer surface to give a resultant divergent hole extending therethrough.

According to a further aspect of the present invention there is provided apparatus for drilling reverse tapered holes, by means of a laser beam across at least one surface element of a pre-formed or pre-assembled structure said apparatus comprising laser input means, a high speed rotating optical

assembly and a fixed spherical lens positioned between said optical assembly and said surface element whereby the input direction of said laser beam is focused on to the outer surface of said surface element, rotation of the beam by means of said rotational optical assembly resulting in a continuous directional change of beam energy through the surface element and a consequent divergent hole.

According to yet a further aspect of the present invention there is provided a method of forming reverse taper slots in a surface element, by means of a laser beam, across at least one surface element of a pre-formed or pre-assembled structure in which each of the said reverse taper slots is formed by projecting said laser beam is focused on to the outer surface of the said surface element at an angle to conform to the required taper of the slot, and laterally oscillating said beam, said oscillating means giving a directional change of beam energy through the material after passing through the fixed cylindrical lens to produce a slot having reverse taper sides.

According to one further aspect of the present invention there is provided apparatus for forming reverse taper slots in a surface element comprising,

a laser beam, an inclined flat, oscillating mirror and a fixed cylindrical lens in which said fixed cylindrical lens is positioned intermediate said inclined mirror and said surface element and whereby said laser beam is deflected by said inclined mirror to give, when oscillated, a directional change of beam energy through the material after passing through the fixed cylindrical lens and a resultant reverse tapered slot.

Embodiments of the present invention will now be described, by way of example only and with reference to the following drawings in which;

Figure 1 is a typical cross-section through a structure manufactured by a superplastic forming and diffusion bonded structure.

Figure 2 is a partial plan view in direction of Arrow 2 in Figure 1

Figure 3 is a cross-section, to a large scale, through one reverse tapered hole.

Figure 4 illustrates one embodiment of apparatus for laser drilling comprising a high speed rotating optical assembly.

Figure 5 illustrates one further embodiment for laser forming a reverse tapered slot by means of an oscillating optical assembly.

Referring to the drawings, Figures 1 and 2 illustrate a portion of a typical structural assembly 1 produced by a superplastic forming and diffusion bonding process, not further described here, but which includes integrally formed outer skin panels 2 and 3 and longitudinal stiffeners 4 to form sealed interspaces 5. This structure could form the outer surface of a wing structure which is to be subjected to laminar flow control by means of induced suction applied through minute perforations 6 formed in the outer skin surface 2. The interspaces therefore comprise, conveniently, fluid flow passageway connectable to a suction source. However, because of the nature of the structure and the method of its construction, an inflation process, the perforations must be introduced into the finally formed structure and to be properly functional must be of reverse taper diverging inwardly from the outer surface 2a. A typical hole 7 is shown to large scale in Figure 3 by way of example. To achieve such a reverse taper a one shot laser process would need to be applied from the undersurface which in view of the nature of the structure is not possible.

One means of achieving such a reverse tapered hole will now be described with reference to Figure 4 in which a high speed rotating optical assembly 8 is positioned above a structural skin 9 with a fixed spherical lens 10 positioned between the said rotating optical assembly 8 and the skin 9. The optical assembly comprises an outer mirror 11 having convergent inner reflective surfaces 12 and 13 and inner mirror 14 having outer reflective surfaces 15 and 16, both the outer mirror 11 and the inner mirror 14 constrained to rotate about an axis of rotation 17 said axis of rotation lying co-incident with the polar axis of the fixed spherical lens. A laser beam 18 enters the optical assembly 8 and is deflected as shown, high speed rotation of the optical assembly shifting the input direction of the beam to pass through the fixed spherical lens 10 which focuses on to the material surface 9. Rotation of the beam on this lens results in a continuous directional change of the beam energy through the material after passing through the focus point at the surface.

The taper angle produced will depend on the focal length of lens used and the position of the beam with respect to the axis of the lens, thus providing a means for controlling the amount of taper.

In certain circumstances it may be preferable to utilise suction slots rather than holes but the same requirement for reverse taper applies along the longitudinal sides. Figure 5 illustrates one embodiment for achieving such a slot in which an inclined flat mirror 19 is positioned as shown above a fixed cylindrical lens 20 which in turn is placed at a suitable distance above the skin panel to be treated. The flat mirror 19 includes lateral oscillating means, not described, whereby it is displaceable to a position 19a. The laser beam 18 is deflected by the mirror 19 to give a directional change of the beam energy through the material after passing through the fixed cylindrical lens and oscillation of the mirror will produce a reverse tapered slot.

CLAIMS

1. A method of drilling a multiplicity of reverse tapered holes, by means of a laser beam, across at least one surface element of a pre-formed or pre-assembled structure in which each of said holes is formed by:-

projecting said laser beam through a fixed spherical lens located above the outer surface, of said surface element, focusing said laser beam on to the said outer surface such that the taper angle of said beam will substantially conform to the required taper of the hole and,

rotating said focused beam about the polar axis of said fixed spherical lens,

whereby a continuous directional change of laser beam energy is effected through the material after passing through the focus point at the outer surface to give a resultant divergent hole extending therethrough.

2. Apparatus for drilling reverse tapered holes, by means of a laser beam across at least one surface element of a pre-formed or pre-assembled structure said apparatus comprising:-

laser input means,

a high speed rotating optical assembly and

a fixed spherical lens positioned between said optical assembly and said surface element

whereby the input direction of said laser beam is focused on to the outer surface of said surface element, rotation of the beam by means of said rotational optical assembly resulting in a continuous directional change of beam energy through the surface element and a consequent divergent hole.

3. A method of forming reverse taper slots in a surface element, by means of a laser beam, across at least one surface element of a pre-formed or pre-assembled structure in which each of the said reverse taper slots is formed by projecting said laser beam is focused on to the outer surface of the said surface element at an angle to conform to the required taper of the slot, and laterally oscillating said beam, said oscillating means giving a directional change of beam energy through the material after passing through the fixed cylindrical lens to produce a slot having reverse taper sides.

4. Apparatus for forming reverse taper slots in a surface element comprising,

a laser beam

an inclined flat, oscillating mirror and

a fixed cylindrical lens

in which said fixed cylindrical lens is positioned intermediate said inclined mirror and said surface element and whereby said laser beam is deflected by said inclined mirror to give, when oscillated, a directional change of beam energy through the material after passing through the fixed cylindrical lens and a resultant reverse tapered slot.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

(i) UK Cl (Edition K) G4A (AFMD, AFMP, AFMG)

(ii) Int Cl (Edition 5) G06F 11/34

Search Examiner
B G WESTERN

Databases (see over)

(i) UK Patent Office

(ii) ON-LINE DATABASE:WPI

Date of Search
11 FEBRUARY 1992

Documents considered relevant following a search in respect of claims 1-3

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2217070 A ELVEREX N.B. FIGURES 3A-3C AND DESCRIPTION	1-3

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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&: Member of the same patent family, corresponding document.

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